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The Majella National Park: a case study for the conservation of plant biodiversity in the Italian Apennines

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Abstract

The Majella National Park (MNP) is a tangible example of the interaction between *ex-situ* and *in-situ* conservation of endemic, rare, or endangered species at a Regional level in the context of the Italian national parks. The MNP has the facilities and carries out activities for the conservation of plant biodiversity: it includes botanical gardens, a seed bank, a nursery, and a network of "guardian farmers", an authentic "granary" in which to protect and conserve biodiversity in and around the Majella massif (central Italy).

Keywords

Ex-situ conservation, plant biodiversity, seed bank, restocking

Introduction

The deterioration of the conservation status of many species is well documented (e.g., Dirzo et al. 2014). Declining biodiversity is due to the burgeoning world human population that is perpetuating the unsustainable use of natural resources (Wilson 2016).

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The overall goal of conservation is to mitigate the loss of biodiversity and preserve ecosystem services, species, and genetic diversity for the future (Schwartz et al. 2017). Conservation has a positive impact on several species (Hoffmann et al. 2010) that could be threatened or even become extinct in the near future (Butchart et al. 2006; Hoffmann et al. 2015). Italy has a rich natural heritage and is at the heart of the Mediterranean Basin, one of the most threatened global biodiversity hotspots, due to a high rate of endemism and strong human impact (Médail 2017; Orsenigo et al. 2018).

In-situ and *ex-situ* conservation measures, achieved *via* several techniques, are employed to conserve genetic diversity (Engelmann and Engels 2002). Among plant conservation strategies, the *in-situ* one has, as its primary focus, the conservation of biological diversity and endeavours to manage and conserve species in their natural habitat; indeed, *in-situ* conservation of ecosystems may offer distinct advantages for many plant species by preserving both genetic and ecological information (Hamilton 1994). *Ex-situ* conservation aims to conserve components of biological diversity outside their natural habitats, while complementing *in-situ* activities, and supporting species recovery (Cochrane et al. 2007).

In-situ conservation is entrusted to protected areas, such as National Parks. Italy counts 24 National Parks, which represent the maximum level of habitat protection according to the Italian legislation; this level equals Category II of protected areas in the IUCN classification (Dudley 2008).

The *ex-situ* techniques can guarantee the conservation of the genetic variability of the germplasm (seeds, pollen, plant parts, spores, etc.) and, therefore, the reproduction of the species to be conserved. This type of conservation is managed mostly by seed banks and botanic gardens (Mounce et al. 2017), *Ex-situ* conservation also plays a crucial role in making available plant materials of certified origin for restocking and land management. Loss of biodiversity due to anthropogenic pressures, such as loss and degradation of habitats, climate change, and spread of invasive species cannot be controlled only by *ex-situ* conservation measures. For this reason, an effective conservation strategy must integrate several conservation methods, this approach being called integrated conservation (McGowan et al. 2017; Piotto et al. 2010). It combines *in-situ* conservation, especially within the Protected Areas, with the *ex-situ* conservation. The Convention on Biological Diversity, in two articles (8, 9), underlines and promotes the importance of integrated approaches that combine several conservation practices (Scarascia-Mugnozza and Perrino 2002).

This study aims to highlight the role of the Majella National Park (MNP) in coordinating integrated *in-situ*/*ex-situ* strategies aimed at the preservation of the natural heritage of the Majella massif and its surroundings. In this context, the Majella Seed Bank (MSB) is a significant player in *ex-situ* conservation.

The Majella massif is a Mediterranean mountain, and this area is considered one of the most threatened in Europe (Gomez-Campo 1985). Predictions of climate change indicate that this genetic, floristic, and community diversity could be significantly affected in the future (Jump and Penuelas 2005; Thuiller et al. 2005; Di Musciano et al. 2020). In the Mediterranean mountains, increasing aridity is the major driver of species loss (Pauli et al. 2012). This trend is likely to continue during the coming decades, insofar as climate models

predict increasing temperatures, decreasing annual precipitation, and an expansion of the dry season in southern Europe (Benito et al. 2011). Due to the high degree of endemism and endangered species in these regions, these mountains have a high risk of biodiversity loss. Greater efforts should be addressed to improve the conservation strategies for Mediterranean mountain species. The survival of these endemic and threatened species requires different and complementary conservation approaches and techniques (Raven 2004).

The territory of the MNP has an extraordinarily rich heritage in terms of biodiversity. Protection and management need to be ensured through diversified and interdependent approaches. The MNP has developed an integrated *in-situ*/*ex-situ* conservation strategies following the conservation actions already conducted in the area since the 1970s *ex-situ*. The "Michele Tenore" Botanical Garden has been carrying out several conservation actions, including management of the *index seminum* since the mid-990s. This action has encouraged the development of conservation strategies integrating scientific and management approaches. The *ex-situ* conservation structures currently run by the Park (the MSB, 'Michele Tenore' and 'Daniela Brescia' botanical gardens, and the nursery) are, thus, the result of a process that has taken place over time and that has encouraged concrete actions to protect and increase awareness in decision makers of the importance of identifying *ex-situ* conservation as a key instrument in support of the institutional objectives for managing protected areas.

In this work, we present the integrated conservation strategy of plant biodiversity set up by the MNP, following state-of-the-art techniques, to preserve its extraordinary natural heritage.

Materials and methods

Study area

The MNP, located in the central Apennines, Italy (Fig. 1), was established in 1995 by National Law 1991, n. 394, to preserve, protect and enhance the high value of the inherent natural, historical, and cultural resources of the area. The Park consists mainly of carbonate mountains, separated by valleys and karst high plateaus, with a broad altitudinal range (130–2,793 m a.s.l.). The Majella massif has more than 60 peaks, with half of them rising above 2,000 m, and includes the second highest peak in the Apennines, Mount Amaro (2,793 m). The landscape is dominated by NW-SE-oriented limestone ridges reaching above the beech tree-line, i.e., Morrone, Rotella, Pizzalto, and Porrarra, and by the Majella massif. These mountains are composed almost exclusively of deep layers of limestone where all the geological eras from the Triassic onwards are represented. A unique periglacial plateau at ca. 2000 m lies above the Majella massif and includes more than 15 smooth summits (Whitehead 1951; Stanisci et al. 2011). The Apennines were repeatedly glaciated during the Pleistocene (Giraudi 2005), while simultaneously the Adriatic Sea retreated resulting in the formation of a broad periglacial plain. During the last glacial maximum, the upper part of the massif was covered by a thick ice layer 30 km^2 wide and more than 200 m thick (Jaurand 1994), with

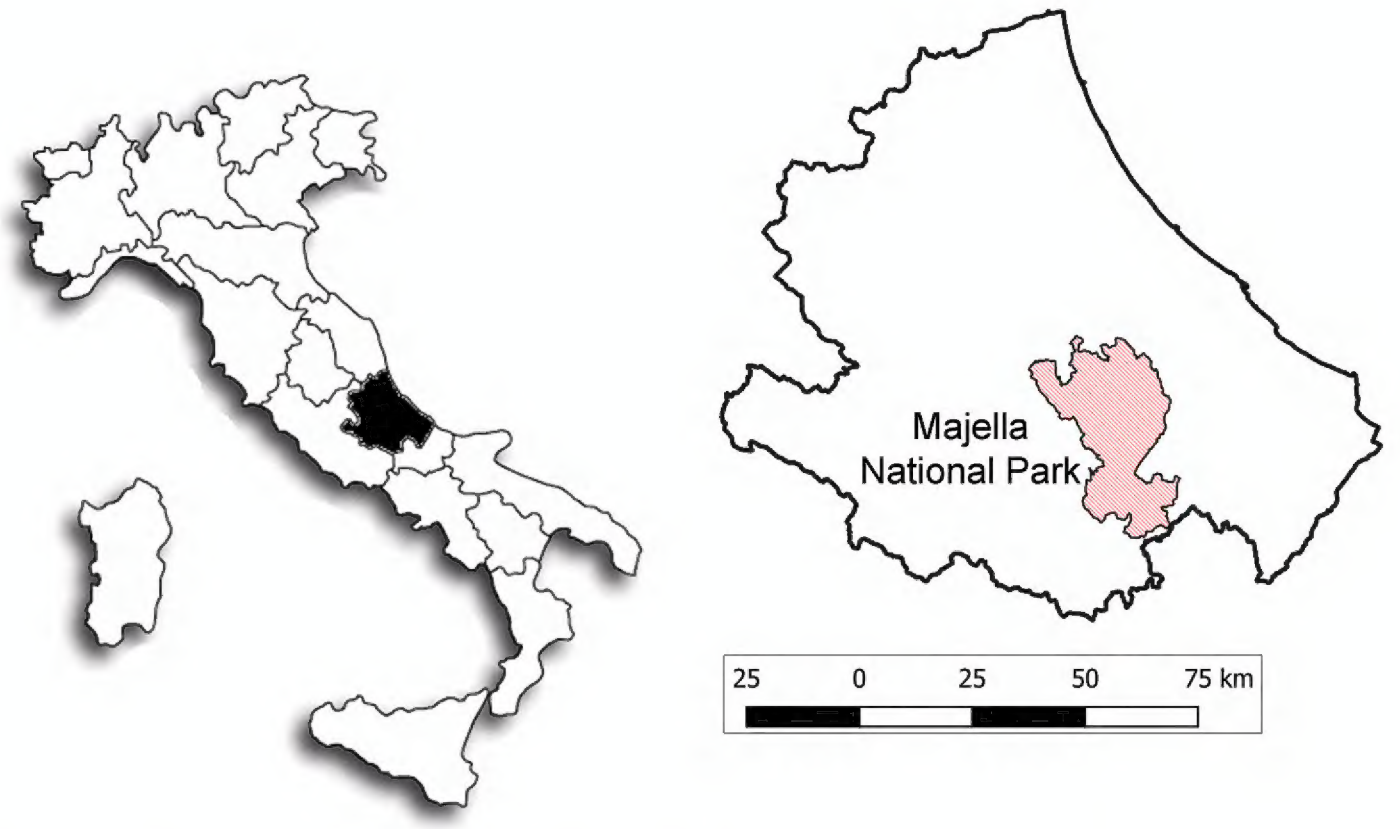

Figure 1. Geographical position of the Majella National Park.

glacial tongues spreading over all the adjacent valleys down to 1330/1400 m of altitude. The Würm glaciation gave origin to macroscopic forms of erosion, circles and moraine deposits; the current periglacial landscape is exposed to frost wedging and long-term snow persistence (7–8 months a year; Stanisci et al. 2005). From a bioclimatic point of view, the study area is included in the alpine biogeographical region (Cervellini et al. 2020) and the climate corresponds to the subalpine-alpine humid type as far as the lower summit is concerned, whereas the other summits belong to the alpine humid type (Blasi 2005). Sub-Mediterranean conditions prevail up to ≈ 1000 m a.s.l. (van Gils et al. 2012). The landscape below 1000 m is a patchwork of villages, farmlands, oak forest fragments (*Quercus pubescens* Willd. subsp. *pubescens*), and shrubs. At mid-elevation (ca. 1000–1750 m), the territory is dominated by contiguous monospecific beech (*Fagus sylvatica* L. subsp. *sylvatica*) forests (van Gils et al. 2010). Secondary montane grasslands, currently unutilized, prevail on south-eastern to south-western slopes. Summer pastoralism above the beech tree-line has been gradually abandoned over the past century.

The Park' territories are part of the Natura 2000 network. The boundaries coincide with a Special Protection Area (SPA) for the conservation of wild birds (established by the Birds Directive 79/409/EEC). Furthermore, within the Park, there are four Special Areas of Conservation (SAC), established by Habitat Directive 92/43/EEC.

The MNP is extremely rich in plant species, indeed its flora stands out for the high number of specific and subspecific taxa, for a total of 2,286 (Conti et al. 2019), including 15 exclusive endemics, such as *Pinguicula fiorii* Tammaro & Pace, *Soldanella minima* Hoppe subsp. *samnitica* Cristof. & Pignatti, *Aquilegia magellensis* F.Conti & Soldano, *Centaurea tenoreana* Willk., *Crepis magellensis* F.Conti & Uzunov. Italian endemic taxa are 201 (8.8%), grouped in 104 genera and 35 families (Conti et al. 2019).

Moreover, the MNP is the *locus classicus* for 49 species and subspecies (Peruzzi et al. 2015, 2019). The Park administration established and maintains two botanical gardens, a seed bank, and a herbarium for preserving and studying the flora of the Park (Di Martino et al. 2016a).

Measures to protect plant biodiversity: Botanical Gardens and Seed Bank

For the *ex-situ* conservation of plant biodiversity, in implementation of art. 9 of the Rio de Janeiro Convention on Biological Diversity, the Park Authority manages two botanical gardens (the "Michele Tenore" at Lama dei Peligni and the "Daniela Brescia" at Sant'Eufemia a Maiella) and the Majella Seed Bank (MSB). These structures aim to collect, study, and conserve seeds of wild species to preserve their genetic heritage.

The "Michele Tenore" Botanical Garden was created in 1995 and currently covers an area of 9,000 m^2. It harbours 433 plant species and is dedicated to the Neapolitan botanist Michele Tenore who visited the area in 1831 and described several species. The "Daniela Brescia" Botanical Garden is located at 900 m a.s.l. in the MNP. It was set up in 2001 and currently includes 545 plant species over a surface area of more than 40,000 m^2. The Garden was designed to contain reproductions of some mountain environments of the central Apennines, like high-altitude cliffs and screes , while an area is dedicated to demonstrative didactic sections, such as the field-showcase of agricultural biodiversity.

The MSB is situated in the "Michele Tenore" Botanical Garden. Its main aim is to preserve particularly rare and/or endangered wild or cultivated species. Seed banks are generally considered a strong and effective tool for long-term biodiversity conservation (Williams et al. 2003; Mattana et al. 2005) and an important potential seed source for the restoration of plant communities (Bakker and Berendse 1999). Furthermore, the ability to store a large diversity in a small space makes seed banking a practical and attractive tool for plant conservation (Liu et al. 2018).

The MSB was established in 2005 to mark the founding of R.I.B.E.S., the Italian Germplasm Bank Network (Rossi et al. 2006; Bonomi et al. 2008), whose founding members include the Park and 15 seed banks throughout Italy. Currently, the MSB is a reference at a Regional level and is a tangible example of the interaction between *ex-situ* and *in-situ* conservation, in the context of Italian national parks. The work of the MSB is inspired by specific international conservation conventions and strategies (Convention on Biological Diversity, CBD 1992; Global Strategy for Plant Conservation GSPC 2012; European Plant Conservation Strategy, EPCS 2002). The MSB *ex-situ* conservation activities mainly focus on rare and/or endangered or endemic alpine belt species, many of which are in the IUCN lists and/or protected by international conventions (Cites, Bern, etc.), the European Community "Habitat" Directive 43/92, Regional Law no. 45/1979 for the protection of Flora in Abruzzo and Red Lists of Italian Plants (Rossi et al. 2013; Orsenigo et al. 2018, 2020). Furthermore, activities relating to restocking projects on plant species included in annex II of the Habitats Directive are underway. The fact that the MSB is managed by a national park is a unique case in Italy.

The Botanical Garden at Sant'Eufemia a Maiella also incorporates the "Native Plants Nursery", aimed exclusively at reproducing (from seed or cuttings) native plant species, particularly the most endangered ones, and/or growing plants for use in the Botanical Gardens or the Park itself. Since 2011, the Sant'Eufemia nursery has been authorised to operate as a commercial nursery (pursuant to D.Lgs 214/2005) and is officially registered in the Producers' Register. In this nursery, 140 species are grown, including perennial herbs, shrubs, trees, and medicinal plants. The nursery's high-quality native plant production is a valid support for public administrations and other public and private botanical gardens (Di Martino et al. 2020).

The Sant'Eufemia Botanical Garden hosts the herbarium which, to date, boasts more than 3,000 specimens, including the critical groups and most endangered species of the Majella massif.

The Park is the coordinator for the FLORANET project, together with the Apennine Flora Research Centre, Legambiente, and other protected areas in Abruzzo. As part of the European Union's LIFE programme, this project aims to preserve the plant species in annex II of the European Directive 43/92/EEC, the "Habitats Directive" (Di Martino et al. 2016a).

Several research activities carried out by the Park support specific *in-situ* conservation measures: management plans for the Natura 2000 sites, monitoring of exclusive endemic flora, a census of monumental trees, monitoring natural populations of native *Pinus nigra* J.F.Arnold subsp. *nigra* var. *italica* Hochst. and *Betula pendula* Roth, and controlling the spread of the invasive alien species *Senecio inaequidens* DC.

Results and discussion

The gardens, the seed bank, the nurseries and the herbarium play an active and integrated role for *in-situ* and *ex-situ* conservation. The cultivated taxa present in the national Red Lists, cultivated endemics, and, finally, all the species stored in the MSB are listed below.

Botanical gardens

The plants grown in the Garden's nursery can be used to (i) reintroduce species that are extinct in the protected areas, (ii) limit the collection of material from the wild in order to maintain the Garden's own collection; (iii) reinforce very small populations of rare species, thereby improving their chances of survival; (iv) encourage the use of native plants for ornamental purposes; (v) encourage the cultivation of native medicinal herbs and traditional fruit trees, thus boosting the use of local species or ecotypes to restore and improve degraded environments.

In Table 1, Red List taxa cultivated in the Botanical Gardens of the MNP are listed, divided by conservation status. At present, nine threatened taxa (CR, EN) and ten Near Threatened (NT) taxa are being cultivated.

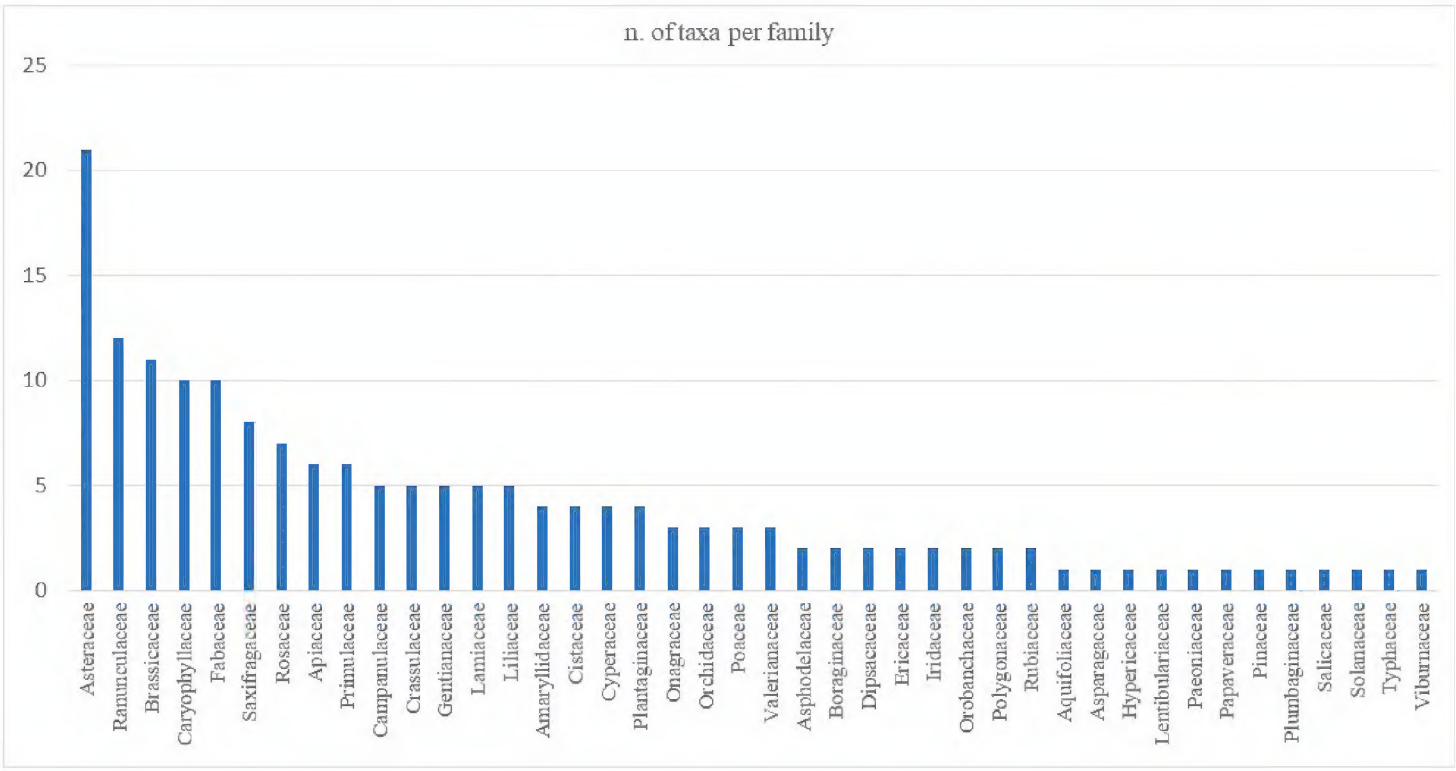

Figure 2. Number of species and subspecies per family stored in the Majella Seed Bank.

A list of endemic taxa cultivated in the two Botanical Gardens is reported in Table 2.

Currently, 52 endemic taxa are being cultivated in the Botanical Gardens, while 226 accessions of wild species are preserved for long-term storage; they were collected over a period of 15 years (from 2005 to 2019). Figure 2 shows the 171 different taxa (species and subspecies) stored in the MSB divided into families. The results highlight the achievement of target 8 for the percentage of species available for restocking, but the Park plans to reach the goal of 75% of the threatened species in the near future.

The most represented families are Asteraceae with 21 taxa, Ranunculaceae with 12, Brassicaceae with 11, Caryophyllaceae and Fabaceae with 10 taxa. Forty-nine taxa are included in the Italian Red List (Rossi et al. 2013, Orsenigo et al. 2018, 2020), and among them, two are Critically endangered (CR): *Bubon macedonicum* L. and *Genista pulchella* Vis. subsp. *aquilana* F.Conti & Manzi; four are Endangered (EN): *Adonis distorta* Ten., *Astragalus aquilanus* Anzal., *Typha minima* Funk ex Hoppe, and *Pinguicula fiorii* Tammaro & Pace; one is Vulnerable (VU): *Oxytropis ocrensis* F.Conti & Bartolucci; 11 are Near Threatened (NT): *Aquilegia magellensis* F.Conti & Soldano, *Carex microcarpa* Bertol. ex Moris, *Crepis magellensis* F.Conti & Uzunov, *Fritillaria montana* Hoppe ex W.D.J.Koch, *Gentiana lutea* L. subsp. *lutea*, *Iris marsica* I.Ricci & Colas., *Jacobaea vulgaris* subsp. *gotlandica* (Neuman) B.Nord., *Leontopodium nivale* (Ten.) Huet ex Hand.-Mazz., *Phyllolepidum rupestre* (Sweet) Trinajstić, *Saxifraga italica* D.A.Webb, *Soldanella minima* Hoppe subsp. *samnitica* Cristof. & Pignatti; 28 are Least Concern (LC); three are Data Deficient (DD).

Five taxa are listed in annex II of the Habitats Directive (1992) in Majella and they are stored in the seed bank (each with a Natura 2000 species code): *Adonis distorta* Ten. (1479), *Androsace mathildae* Levier (1630), *Astragalus aquilanus* Anzal. (priority – 1558), *Cypripedium calceolus* L. (1902), *Himantoglossum adriaticum* H.Baumann (4104). These five species are all present in the directive of the Park's territory, therefore 100% of the

Table 1. Species included in the updated national Red Lists and cultivated in the Botanical Gardens of the Majella National Park. DB – "Daniela Brescia" Botanical Garden; MT – "Michele Tenore" Botanical Garden.

Family	Species	Status IUCN (Rossi et al.2013; Orsenigo et al.2018, 2020)	Botanical Garden
Sapindaceae	*Acer cappadocicum* Gled. subsp. *lobelii* (Ten.) A.E.Murray	LC	DB,MT
Ranunculaceae	*Adonis vernalis* L.	EN	MT
Amaryllidaceae	*Allium commutatum* Guss.	LC	MT
Primulaceae	*Androsace mathildae* Levier	LC	DB
Ranunculaceae	*Aquilegia magellensis* F.Conti & Soldano	NT	DB, MT
Fabaceae	*Astragalus aquilanus* Anzal.	EN	DB, MT
Brassicaceae	*Aubrieta columnae* Guss. subsp. *columnae*	NT	DB, MT
Apiaceae	*Bubon macedonicum* L.	CR	MT
Campanulaceae	*Campanula fragilis* Cirillo subsp. *cavolinii* (Ten.) Damboldt	LC	DB, MT
Cyperaceae	*Carex buxbaumii* Wahlenb.	EN	DB
Asteraceae	*Centaurea scannensis* Anzal., Soldano & F.Conti	EN	DB, MT
Asteraceae	*Centaurea tenoreana* Willk.	LC	DB, MT
Plantaginaceae	*Cymbalaria pallida* (Ten.) Wettst.	LC	DB, MT
Caryophyllaceae	*Dianthus guliae* Janka	EN	DB
Orchidaceae	*Epipactis palustris* (L.) Crantz	NT	DB
Amaryllidaceae	*Galanthus nivalis* L.	LC	DB
Gentianaceae	*Gentiana lutea* L. subsp. *lutea*	NT	DB, MT
Plumbaginaceae	*Goniolimon italicum* Tammaro, Pignatti & Frizzi	EN	MT
Iridaceae	*Iris marsica* I. Ricci & Colas.	NT	DB, MT
Asteraceae	*Klasea lycopifolia* (Vill.) Á.Löve & D.Löve	NT	DB, MT
Asteraceae	*Leucanthemum coronopifolium* Vill. subsp. *tenuifolium* (Guss.) Vogt & Greuter	LC	DB, MT
Brassicaceae	*Phyllolepidum rupestre* (Sweet) Trinajstić	NT	DB, MT
Asparagaceae	*Ruscus aculeatus* L.	NT	DB
Salicaceae	*Salix pentandra* L.	EN	DB, MT
Saxifragaceae	*Saxifraga porophylla* Bertol. subsp. *porophylla*	LC	DB, MT
Poaceae	*Sesleria juncifolia* Wulfen ex Suffren subsp. *juncifolia*	LC	MT
Primulaceae	*Soldanella minima* Hoppe subsp. *samnitica* Cristof. & Pignatti	NT	DB
Typhaceae	*Typha minima* Funk ex Hoppe	EN	MT
Lentibulariaceae	*Utricularia australis* R.Br.	NT	MT

species listed in annex II are preserved in the seed bank. Amongst these, *Astragalus aquilanus* and *Androsace mathildae* are narrow endemics to the Abruzzo Region, *Adonis distorta* is endemic to the central Apennines, while the two Orchidaceae, although extremely localized (especially *Cypripedium calceolus*), show a wider distribution.

During the past years, many species have been studied and several scientific articles published by the seed bank working group; these were inherent to the ecology of germination, the morphometry of seeds, seed dispersal mechanisms, etc. (Frattaroli et al. 2013; Di Martino et al. 2014, 2015; Di Cecco et al. 2017a, 2017c, 2018, 2019; Di Musciano et al. 2018).

These studies are carried out in order to support the preservation of plant germplasm and *in-situ* conservation activities. One of the main projects undertaken by the MSB is the EU-funded Life Floranet that aims to preserve species and ecosystems within the Natura 2000 network (Di Martino et al. 2016a). For this project, which

Table 2. List of Italian endemic taxa (Peruzzi et al. 2014; Bartolucci et al. 2018) cultivated in the Botanical Gardens of the Majella National Park. DB – "Daniela Brescia" Botanical Garden; MT – "Michele Tenore" Botanical Garden. In boldface endemic taxa of the central Apennines.

Family	Endemic species (Peruzzi et al. 2014; Bartolucci et al. 2018)	Botanical Garden
Sapindaceae	*Acer cappadocicum* Gled. subsp. *lobelii* (Ten.) A.E.Murray	DB, MT
Asteraceae	***Achillea barrelieri* (Ten.) Sch.Bip. subsp. *barrelieri***	DB
Asteraceae	*Achillea tenorei* Grande	DB, MT
Brassicaceae	***Alyssum cuneifolium* Ten.**	DB
Brassicaceae	*Alyssum diffusum* Ten. subsp. *diffusum*	DB
Primulaceae	***Androsace mathildae* Levier**	DB
Primulaceae	***Androsace vitaliana* (L.) Lapeyr. subsp. *praetutiana* (Buser ex Sünd.) Kress**	DB
Asteraceae	***Anthemis cretica* L. subsp. *petraea* (Ten.) Greuter**	DB
Ranunculaceae	***Aquilegia magellensis* F.Conti & Soldano**	DB, MT
Caryophyllaceae	*Arenaria bertolonii* Fiori	MT
Plumbaginaceae	*Armeria gracilis* Ten. subsp. *gracilis*	DB
Fabaceae	***Astragalus aquilanus* Anzal.**	DB, MT
Brassicaceae	*Aubrieta columnae* Guss. subsp. *columnae*	DB, MT
Campanulaceae	***Campanula fragilis* Cirillo subsp. *cavolinii* (Ten.) Damboldt**	DB, MT
Asteraceae	*Centaurea ambigua* Guss. subsp. *ambigua*	DB, MT
Asteraceae	***Centaurea ambigua* Guss. subsp. *nigra* (Fiori) Pignatti**	DB
Asteraceae	***Centaurea ceratophylla* Ten. subsp. *ceratophylla***	DB, MT
Asteraceae	***Centaurea scannensis* Anzal., Soldano & F.Conti**	DB, MT
Asteraceae	*Centaurea tenoreana* Willk.	DB, MT
Caryophyllaceae	*Cerastium tomentosum* L.	DB, MT
Rosaceae	*Cotoneaster nebrodensis* (Guss.) K.Koch	MT
Plantaginaceae	***Cymbalaria pallida* (Ten.) Wetts**	DB, MT
Boraginaceae	*Cynoglossum magellense* Ten.	MT
Caryophyllaceae	*Dianthus carthusianorum* L. subsp. *tenorei* (lacaita) Pignatti	DB
Caryophyllaceae	*Dianthus guliae* Janka	DB
Plantaginaceae	*Digitalis micrantha* Roth ex Schweigg.	DB
Brassicaceae	*Erysimum pseudorhaeticum* Polatschek	DB, MT
Euphorbiaceae	***Euphorbia gasparrinii* Boiss. subsp. *samnitica* (Fiori) Pignatti**	DB
Rubiaceae	*Galium lucidum* All. s.l.	DB
Rubiaceae	*Galium magellense* Ten.	DB
Geraniaceae	*Geranium austroapenninum* Aedo	DB
Plumbaginaceae	***Goniolimon italicum* Tammaro, Pignatti & Frizzi**	MT
Iridaceae	***Iris marsica* I. Ricci & Colas.**	DB, MT
Asteraceae	*Jacobaea alpina* (L.) Moench subsp. *samnitum* (Nyman) Peruzzi	DB
Asteraceae	***Leucanthemum coronopifolium* Vill. subsp. *tenuifolium* (Guss.) Vogt & Greuter**	DB, MT
Asteraceae	*Leucanthemum tridactylites* (A.Kern. & Huter ex Porta & Rigo) Huter, Porta & Rigo	DB, MT
Plantaginaceae	*Linaria purpurea* (L.) Mill.	DB
Caprifoliaceae	*Lomelosia crenata* (Cirillo) Greuter & Burdet subsp. *pseudisetensis* (Lacaita) Greuter & Burdet	DB, MT
Caryophyllaceae	*Mcneillia graminifolia* (Ard.) Dillenb. & Kadereit subsp. *rosanoi* (Ten.) F.Conti, Bartolucci, Iamonico & Del Guacchio	DB
Boraginaceae	*Onosma echioides* (L.) L. subsp. *echioides*	DB, MT
Paeoniaceae	***Paeonia officinalis* L. subsp. *italica* N.G.Passal. & Bernardo**	DB, MT
Brassicaceae	***Phyllolepidum rupestre* (Sweet) Trinajstić**	DB, MT
Boraginaceae	*Pulmonaria vallarsae* A.Kern. subsp. *apennina* (Cristof. & Puppi) L.Cecchi & Selvi	DB
Saxifragaceae	***Saxifraga exarata* Vill. subsp. *ampullacea* (Ten.) D.A.Webb**	DB
Saxifragaae	***Saxifraga italica* D.A. Webb**	DB
Saxifragaceae	*Saxifraga oppositifolia* L. s.l.	DB
Saxifragaae	*Saxifraga porophylla* Bertol. subsp. *porophylla*	DB, MT
Crassulaceae	*Sedum magellense* Ten. subsp. *magellense*	DB
Poaceae	*Sesleria nitida* Ten. subsp. *nitida*	DB, MT
Caryophyllaceae	***Silene notarisii* Ces.**	DB, MT
Primulaceae	***Soldanella minima* Hoppe subsp. *samnitica* Cristof. & Pignatti**	DB
Lamiaceae	*Stachys italica* Mill.	DB

MSB LIFE17A07
Iris marsica
Semi provenienti da
G.B. Sant'Eufemia - PRSV Terranera.
Derivante da test di germinazion
1% - 5,7 - 20°- 12 h

Figure 3. Plants of *Iris marsica* grown in the Majella National Park nursery).

is still in progress, 10 restockings has been scheduled, divided by species and action (Table 3). All the plant material used for restocking came from the MSB and the Sant'Eufemia nursery (Figure 3).

The applied strategies of the MNP are essential to perform concrete actions for species conservation. Such actions go from the collection of seeds in nature, *in-vitro* propagation, seed reproduction long-term storage, *in-situ* restocking up to the creation

Table 3. List of species, places of intervention and number of individuals used for restocking actions within the Life Floranet project. MNP – Majella National Park; SVRP – Sirente Velino Regional Park; ALMNP – Abruzzo, Lazio and Molise National Park.

Taxon	Park	Localities	n. of plant
Astragalus aquilanus Anzal.	MNP	Cansano	100
Astragalus aquilanus Anzal.	MNP	Pacentro	100
Astragalus aquilanus Anzal.	ALMNP	Ortona dei Marsi	100
Androsace mathildae Levier	MNP	Pesco Falcone	50
Iris marsica I.Ricci & Colas.	ALMNP	Camosciara	100
Cypripedium calceolus L.	MNP	Valle di Macchialunga	100*
Cypripedium calceolus L.	ALMNP	Camosciara	100*
Jacobaea vulgaris subsp. *gotlandica* (Neuman) B.Nord.	SVRP	Piani di Pezza	100
Jacobaea vulgaris subsp. *gotlandica* (Neuman) B.Nord.	SVRP	Piani di Pezza (laghetto)	100
Klasea lycopifolia (Vill.) Á.Löve & D.Löve	SVRP	Campo Felice	100

* Due to the long growth times, the planned restocking actions will be carried out in the coming years.

of new populations. The functionality and operation of the structures, that are already well established for *ex-situ* conservation, have been tested on restocking actions.

The restocking actions were carried out not only within the boundary of the MNP, but were also extended to other areas of central Italy. In this context, considering that from the 67,620 seed accessions of native plants stored in European seed banks (ENSCOBASE) only 64 (0.09%) were used in translocation programs (Abeli and Dixon 2016), the MNP plays a crucial role in carrying out these strategies and in monitoring endemic or rare species, thereby avoiding the risk of extinction (Dalrymple and Abeli 2019). To date, eight accessions of the MSB have been used for restocking actions. The total number of accessions preserved in MSB is 256, consequently, the percentage of accessions used for restocking is 3.125%, which is significantly higher than the percentage indicated by Abeli and Dixon (2016). Such actions provide exceptionally strong support to the MNP by making use of a truly integrated conservation strategy through the concerted action of its *in-situ* / *ex-situ* facilities.

The amount of seeds stored in the MSB is growing constantly, both in terms of number of species and the area covered. At a Regional level, this represents a way to preserve the genetic resources of both wild species (including trees) and cultivated species of agricultural, culinary, and ornamental interest. The MSB is a landmark in Italy as an example of integration between *ex-situ* and *in-situ* conservation.

The strong effort for *ex-situ* conservation made by the MNP is confirmed by the high number of conserved species. Indeed one-third of the Italian endemic species of the Park (68 species out of 201) and one-third of the species present in the Red Lists (65 species out of 195) are conserved at the Botanical Gardens and in the seed bank. Future collection programmes will be focused on the missing endangered and endemic taxa. The main aim is to achieve the conservation and/or cultivation of at least 75% of the threatened and endemic taxa. This will be done essentially within the Park's territory without, however, excluding species from the Abruzzo Administrative Region and throughout the Apennines.

As regards the agricultural heritage, more than 150 Crop Wild Relatives (CWR; Di Martino et al. 2016c) and 61 native agricultural varieties (Di Santo and Di Cecco 2015) have been identified within the MNP. Conservation plans for the CWR and landraces are made in accordance with the FAO Treaty and the Nagoya International Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization as per the convention on biological diversity. Several CWR species are cultivated and conserved in both Botanical Gardens. For both wild and cultivated taxa, in vivo cultivation and reproduction is a fundamental step towards conservation planning within protected areas (Heywood, 2019). On the other hand, seeds are stored in the MSB, also for studies relating to reproductive biology (Di Cecco et al. 2019). For some species, such as *Secale strictum* (C.Presl) C.Presl subsp. *strictum*, *Apium graveolens* L., and some species of *Lathyrus*, the number of individuals, and the status of populations are being monitored. Moreover, germination tests were carried out to increase knowledge about seed storage and germination niche (Di Cecco et al. 2017b).

The seed bank also stores seed from native local landraces recovered as part of the "Let's Grow Diversity" project. Conserving these landraces is important because they are the result of a long, balanced co-evolution over centuries between Man and nature (Hawkes et al. 2012). The most significant landraces include "Solina" and "Marzuolo" wheats and "Caffè" and "Socere e Nore" beans.

All these actions suggest as an integrated strategy from the seed bank to field cultivation and restoking action is crucial for biodiversity conservation. Furthermore, the collaborations with other botanical gardens and germplasm banks are always desirable to exchange knowledge, procedures, and techniques and duplicate collections.

Conclusions

Cooperation among the structures of the Park (botanical gardens, seed bank, herbarium, and nursery) allows the development of complete conservation programmes, from collection, study, reproduction, cultivation to *in-situ* restocking. Meanwhile, the contribution of the *ex-situ* structures is important for achieving the aims of a National Park. In particular, as indicated by Italian legislation (Law 394/91) on protected areas, we have developed conservation plans for plant species and promoted educational and scientific research activities. In conclusion, the MNP's conservation activities have proved to be effective, as demonstrated by the restocking actions undertaken for the Life FLORANET project. In particular, the seed bank has proved to be extremely useful for studies on germination ecology of rare taxa. In the coming years, the MSB will certainly increase the number of accessions (Table 4), thus guaranteeing greater efficiency in safeguarding rare, endemic and threatened taxa.

At present, 33.3% of the MNP's species present in the Red List are stored in the MSB. For the endemic taxa, 40 are stored in the MSB (33.8% of the endemic species of the Park).

Table 4. List of taxa stored at the Majella Seed Bank. The nomenclature and the systematic order of the families follows the updated checklists of the vascular flora native and alien to Italy (Bartolucci et al. 2018; Galasso et al. 2018). Taxa are ordered alphabetically within each family. For each taxon, the accepted name, main synonyms, and the Italian endemic or alien status are also reported. Abbreviations or symbols used in the floristic list preceding species/subspecies name are: Distribution: Italian endemic taxa, including Malta and Corsica (Peruzzi et al. 2014; Bartolucci et al. 2018): "E"; Taxa narrowly endemic to the Maiella National Park (Conti et al. 2019): "EE"; Cryptogenic (status at the national level, see Bartolucci et al. 2018): "C", a doubtfully native taxon, whose origin of occurrence in Italy is unknown; Archaeophyte (status at the national level, see Galasso et al. 2018): "A"; The IUCN status is indicated according to the following publications: Lista Rossa della Flora Italiana. 1. Policy Species e altre specie minacciate (Rossi et al. 2013); Red Listing plants under full national responsibility: extinction risks and threats in the vascular flora endemic to Italy (Orsenigo et al. 2018); Red list of threatened vascular plants in Italy (Orsenigo et al. 2020). The accessions of local agronomic landraces are shown at the end of the table.

Family	Species name	Distribution	Red list of threatened plants in Italy (2020)	Red list of threatened vascular plants in Italy (2018)	Italian Red List (2013)
Amaryllidaceae	*Allium commutatum* Guss.		LC		
Amaryllidaceae	*Allium lusitanicum* Lam.				
Amaryllidaceae	*Allium oleraceum* L. subsp. *oleraceum*				
Amaryllidaceae	*Allium sphaerocephalon* L. subsp. *sphaerocephalon*				
Apiaceae	*Bubon macedonicum* L.		CR		CR
Apiaceae	*Coristospermum cuneifolium* (Guss.) Bertol.	E		LC	
Apiaceae	*Crithmum maritimum* L.				
Apiaceae	*Siler montanum* Crantz subsp. *siculum* (Spreng.) Iamonico, Bartolucci & F.Conti	E		LC	
Apiaceae	*Trinia dalechampii* (Ten.) Janch.				
Aquifoliaceae	*Ilex aquifolium* L.				
Asparagaceae	*Muscari neglectum* Guss. ex Ten.				
Asphodelaceae	*Asphodeline lutea* (L.) Rchb.				
Asphodelaceae	*Asphodelus macrocarpus* Parl. subsp. *macrocarpus*				
Asteraceae	*Achillea barrelieri* (Ten.) Sch. Bip. subsp. *barrelieri*	E		LC	
Asteraceae	*Achillea tenorei* Grande	E		LC	
Asteraceae	*Artemisia eriantha* Ten.				
Asteraceae	*Carduus chrysacanthus* Ten.				
Asteraceae	*Centaurea ceratophylla* Ten. subsp. *ceratophylla*	E		LC	
Asteraceae	*Centaurea tenoreana* Willk.	EE		LC	
Asteraceae	*Crepis magellensis* F. Conti & Uzunov	EE		NT	
Asteraceae	*Crepis pygmaea* L.				
Asteraceae	*Doronicum columnae* Ten.				
Asteraceae	*Erigeron epiroticus* (Vierh.) Halácsy				
Asteraceae	*Eupatorium cannabinum* L. subsp. *cannabinum*				
Asteraceae	*Helichrysum italicum* (Roth) G.Don subsp. *italicum*				

Family	Species name	Distribution	Red list of threatened plants in Italy (2020)	Red list of threatened vascular plants in Italy (2018)	Italian Red List (2013)
Asteraceae	*Jacobaea alpina* (L.) Moench subsp. *samnitum* (Nyman) Peruzzi	E		LC	
Asteraceae	*Jacobaea vulgaris* subsp. *gotlandica* (Neuman) B. Nord.		NT		
Asteraceae	*Jurinea mollis* (L.) Rchb. subsp. *mollis*				
Asteraceae	*Klasea lycopifolia* (Vill.) Á.Löve & D.Löve				
Asteraceae	*Leontopodium nivale* (Ten.) Huet ex Hand.-Mazz.		NT		
Asteraceae	*Mycelis muralis* (L.) Dumort.				
Asteraceae	*Omalotheca diminuta* (Braun-Blanq.) Bartolucci & Galasso				
Asteraceae	*Scorzoneroides montana* (Lam.) Holub subsp. *breviscapa* (DC.) Greuter	E		LC	
Asteraceae	*Tragopogon porrifolius* L.				
Boraginaceae	*Cynoglossum magellense* Ten.	E		LC	
Boraginaceae	*Myosotis graui* Selvi	E		LC	
Brassicaceae	*Alyssum cuneifolium* Ten.	E			
Brassicaceae	*Alyssum diffusum* Ten. subsp. *diffusum*	E		LC	
Brassicaceae	*Arabis alpina* L. subsp. *caucasica* (Willd.) Briq.				
Brassicaceae	*Aurinia sinuata* (L.) Griseb.				
Brassicaceae	*Draba aizoides* L. subsp. *aizoides*				
Brassicaceae	*Iberis saxatilis* L. subsp. *saxatilis*				
Brassicaceae	*Isatis apennina* Ten. ex Grande				
Brassicaceae	*Isatis tinctoria* L. subsp. *tinctoria*	A			
Brassicaceae	*Matthiola incana* (L.) W.T:Aiton subsp. *incana*				
Brassicaceae	*Noccaea stylosa* (Ten.) Rchb.	E		LC	
Brassicaceae	*Phyllolepidum rupestre* (Sweet) Trinajstić	E		NT	
Campanulaceae	*Campanula fragilis* Cirillo subsp. *cavolinii* (Ten.) Damboldt	E		LC	
Campanulaceae	*Campanula rapunculus* L.				
Campanulaceae	*Campanula scheuchzeri* Vill. subsp. *scheuchzeri*				
Campanulaceae	*Campanula trachelium* L. subsp. *trachelium*				
Campanulaceae	*Edraianthus graminifolius* (L.) A.DC. subsp. *graminifolius*				
Caryophyllaceae	*Arenaria bertolonii* Fiori	E	LC		
Caryophyllaceae	*Arenaria grandiflora* L. subsp. *grandiflora*				
Caryophyllaceae	*Cerastium thomasii* Ten.	E		LC	
Caryophyllaceae	*Cerastium tomentosum* L.	E		LC	
Caryophyllaceae	*Drypis spinosa* L. subsp. *spinosa*				
Caryophyllaceae	*Heliosperma pusillum* (Waldst. & Kit.) Rchb. subsp. *pusillum*				

Family	Species name	Distribution	Red list of threatened plants in Italy (2020)	Red list of threatened vascular plants in Italy (2018)	Italian Red List (2013)
Caryophyllaceae	*Sabulina verna* (L.) Rchb. subsp. *verna*				
Caryophyllaceae	*Silene acaulis* (L.) Jacq. subsp. *bryoides* (Jord.) Nyman				
Caryophyllaceae	*Silene ciliata* Pourr. subsp. *graefferi* (Guss.) Nyman				
Caryophyllaceae	*Silene notarisii* Ces.	E		DD	
Cistaceae	*Cistus creticus* L. subsp. *creticus*				
Cistaceae	*Cistus creticus* L. subsp. *eriocephalus* (Viv.) Greuter & Burdet				
Cistaceae	*Fumana ericifolia* Wallr.				
Cistaceae	*Helianthemum nummularium* (L.) Mill. subsp. *obscurum* (Čelak.) Holub				
Crassulaceae	*Petrosedum rupestre* (L.) P.V.Heath				
Crassulaceae	*Sedum album* L. subsp. *micranthum* (Bast. ex DC.) Syme				
Crassulaceae	*Sedum atratum* L.				
Crassulaceae	*Sedum dasyphyllum* L. subsp. *dasyphyllum*				
Crassulaceae	*Umbilicus horizontalis* (Guss.) DC.				
Cyperaceae	*Carex kitaibeliana* Degen ex Bech.				
Cyperaceae	*Carex microcarpa* Bertol. ex Moris	E	NT		
Cyperaceae	*Carex myosuroides* Vill.				
Cyperaceae	*Eriophorum latifolium* Hoppe				
Dipsacaceae	*Lomelosia crenata* (Cirillo) Greuter & Burdet subsp. *pseudisetensis* (Lacaita) Greuter & Burdet	E		LC	
Dipsacaceae	*Lomelosia graminifolia* (L.) Greuter & Burdet subsp. *graminifolia*				
Ericaceae	*Arctostaphylos uva-ursi* (L.) Spreng.				
Ericaceae	*Orthilia secunda* (L.) House				
Fabaceae	*Anthyllis montana* L. subsp. *jacquinii* (Rchb.f.) Rohlena				
Fabaceae	*Astragalus aquilanus* Anzal.	E		EN	EN
Fabaceae	*Coronilla valentina* L.				
Fabaceae	*Genista pulchella* Vis. subsp. *aquilana* F. Conti & Manzi	E			CR
Fabaceae	*Lathyrus clymenum* L.				
Fabaceae	*Lathyrus odoratus* L.	E		LC	
Fabaceae	*Lathyrus oleraceus* Lam.				
Fabaceae	*Ononis rotundifolia* L.				
Fabaceae	*Oxytropis ocrensis* F. Conti & Bartolucci	E		VU*	
Fabaceae	*Trifolium thalii* Vill.				
Gentianaceae	*Gentiana cruciata* L. subsp. *cruciata*				
Gentianaceae	*Gentiana dinarica* Beck				
Gentianaceae	*Gentiana lutea* L. subsp. *lutea*				NT

Family	Species name	Distribution	Red list of threatened plants in Italy (2020)	Red list of threatened vascular plants in Italy (2018)	Italian Red List (2013)
Gentianaceae	*Gentiana orbicularis* Schur				
Gentianaceae	*Gentiana verna* L. subsp. *verna*				
Hypericaceae	*Hypericum richeri* Vill. subsp. *richeri*				
Iridaceae	*Chamaeiris lorea* (Janka) Peruzzi, F.Conti & Bartolucci				
Iridaceae	*Iris marsica* I. Ricci & Colas.	E		NT	NT
Lamiaceae	*Melissa officinalis* L. subsp. *officinalis*	C			
Lamiaceae	*Phlomis fruticosa* L.				
Lamiaceae	*Salvia officinalis* L. subsp. *officinalis*				
Lamiaceae	*Teucrium flavum* L. subsp. *flavum*				
Lamiaceae	*Thymus zygiformis* Heinr. Braun var. *magellensis* (Ronniger) Bartolucci & J.Walter		DD		
Lentibulariaceae	*Pinguicula fiorii* Tammaro & Pace	EE		EN	
Liliaceae	*Fritillaria montana* Hoppe ex W.D.J.Koch				NT
Liliaceae	*Lilium martagon* L.				
Linaceae	*Linum alpinum* Jacq.				
Linaceae	*Linum usitatissimum* L. subsp. *angustifolium* (Huds.) Thell.				
Linaceae	*Linum viscosum* L.				
Onagraceae	*Chamaenerion angustifolium* (L.) Scop.				
Onagraceae	*Chamaenerion dodonaei* (Vill.) Schur ex Fuss				
Onagraceae	*Epilobium hirsutum* L.				
Orchidaceae	*Cypripedium calceolus* L.				LC
Orchidaceae	*Himantoglossum adriaticum* H.Baumann				LC
Orchidaceae	*Limodorum abortivum* (L.) Sw.				
Orobanchaceae	*Pedicularis hoermanniana* K.Malý				
Orobanchaceae	*Rhinanthus alectorolophus* (Scop.) Pollich subsp. *alectorolophus*				
Paeoniaceae	*Paeonia officinalis* L. subsp. *italica* N.G.Passal. & Bernardo	E		LC	
Papaveraceae	*Papaver alpinum* L. subsp. *alpinum*				
Pinaceae	*Pinus mugo* Turra subsp. *mugo*				
Plantaginaceae	*Erinus alpinus* L.				
Plantaginaceae	*Linaria alpina* (L.) Mill.				
Plantaginaceae	*Plantago atrata* Hoppe subsp. *fuscescens* (Jord.) Pilg.				
Plantaginaceae	*Veronica aphylla* L. subsp. *aphylla*				
Plumbaginaceae	*Armeria gracilis* Ten. subsp. *majellensis* (Boiss.) Arrigoni	E		LC	
Poaceae	*Briza maxima* L.				
Poaceae	*Briza minor* L.				

Family	Species name	Distribution	Red list of threatened plants in Italy (2020)	Red list of threatened vascular plants in Italy (2018)	Italian Red List (2013)
Poaceae	*Secale strictum* (C.Presl) C.Presl subsp. *strictum*				
Polygonaceae	*Bistorta vivipara* (L.) Delarbre				
Polygonaceae	*Rumex arifolius* All.				
Primulaceae	*Androsace mathildae* Levier	E		LC	LC
Primulaceae	*Androsace villosa* L. subsp. *villosa*				
Primulaceae	*Androsace vitaliana* (L.) Lapeyr. subsp. *praetutiana* (Buser ex Sünd.) Kress	E		LC	
Primulaceae	*Primula intricata* Gren. & Godr.				
Primulaceae	*Primula veris* L. subsp. *columnae* (Ten.) Maire & Petitm.				
Primulaceae	*Soldanella minima* Hoppe subsp. *samnitica* Cristof. & Pignatti	EE		NT	
Ranunculaceae	*Actaea spicata* L.				
Ranunculaceae	*Adonis distorta* Ten.	E		EN	EN
Ranunculaceae	*Aquilegia dumeticola*Jord.				
Ranunculaceae	*Aquilegia magellensis* F. Conti & Soldano	EE		NT	
Ranunculaceae	*Clematis vitalba* L.				
Ranunculaceae	*Pulsatilla alpina* (L.) Delarbre subsp. *millefoliata* (Bertol.) D.M.Moser				
Ranunculaceae	*Pulsatilla montana* (Hoppe) Rchb. subsp. *montana*				
Ranunculaceae	*Ranunculus magellensis* Ten.	E		DD	
Ranunculaceae	*Ranunculus seguieri* Vill. subsp. *seguieri*				
Ranunculaceae	*Thalictrum aquilegiifolium* L. subsp. *aquilegiifolium*				
Ranunculaceae	*Thalictrum simplex* L. subsp. *simplex*				
Ranunculaceae	*Trollius europaeus* L.				
Rosaceae	*Dryas octopetala* L. subsp. *octopetala*				
Rosaceae	*Geum molle* Vis. & Pančić				
Rosaceae	*Potentilla crantzii* (Crantz) Beck ex Fritsch subsp. *crantzii*				
Rosaceae	*Pyracantha coccinea* M.Roem.				
Rosaceae	*Sorbus aria* (L.) Crantz				
Rosaceae	*Sorbus chamaemespilus* (L.) Crantz				
Rosaceae	*Sorbus mougeotii* Soy.-Will. & Godr.				
Rubiaceae	*Galium corrudifolium* Vill.				
Rubiaceae	*Galium magellense* Ten.	E		LC	
Salicaceae	*Salix retusa* L.				
Saxifragaceae	*Saxifraga adscendens* L. subsp. *adscendens*				
Saxifragaceae	*Saxifraga caesia* L.				
Saxifragaceae	*Saxifraga callosa* Sm. subsp. *callosa*				
Saxifragaceae	*Saxifraga exarata* Vill. subsp. *ampullacea* (Ten.) D.A.Webb	E		LC	

Family	Species name	Distribution	Red list of threatened plants in Italy (2020)	Red list of threatened vascular plants in Italy (2018)	Italian Red List (2013)
Saxifragaceae	*Saxifraga italica* D.A.Webb	E		NT	
Saxifragaceae	*Saxifraga oppositifolia* L. subsp. *speciosa* (Dörfl. & Hayek) Engl. & Irmsh.	E		LC	
Saxifragaceae	*Saxifraga paniculata* Mill.				
Saxifragaceae	*Saxifraga rotundifolia* L. subsp. *rotundifolia*				
Solanaceae	*Atropa bella-donna* L.				
Typhaceae	*Typha minima* Funk ex Hoppe				EN
Valerianaceae	*Centranthus ruber* (L.) DC. subsp. *ruber*				
Valerianaceae	*Valeriana montana* L.				
Valerianaceae	*Valeriana saliunca* All.				
Viburnaceae	*Viburnum lantana* L.				

Local agronomic landraces

Family	Species name	Landraces name
Fabaceae	*Phaseolus vulgaris* L.	40 giorni
Fabaceae	*Phaseolus vulgaris* L.	a caffè
Fabaceae	*Phaseolus vulgaris* L.	aquilano
Fabaceae	*Phaseolus vulgaris* L.	socere e nore
Fabaceae	*Vicia faba* L.	mezza fava
Poaceae	*Triticum aestivum* L.	solina
Poaceae	*Triticum aestivum* L.	casorella
Poaceae	*Triticum dicoccon* Schrank	farro del Sangro
Poaceae	*Triticum dicoccon* Schrank	levese
Poaceae	*Triticum durum* Desf.	rosciola
Poaceae	*Triticum durum* Desf.	ruscia
Poaceae	*Triticum durum* Desf.	marzuolo

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Supplementary material 1

Complete list of taxa stored at the MSB

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Data type: checklist

Explanation note: List of taxa stored at the Majella Seed Bank. Where present, IUCN status is indicated.

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